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ABSTRACT

The Modified-Revised Science Teacher's Behavior Inventory (MR-STBI) was used in earlier studies to analyze the teaching strategies emphasized in instruction in science classrooms. This analysis showed changes in teaching strategies that occurred as a result of science teachers' professional development through longer-term modeled, laboratory-driven instruction; group planning for such instruction; and mentoring by college-level faculty as teachers taught science back in their schools. As an outgrowth of these earlier studies, it became clear that the MR-STBI did not effectively address the extent of inquiry in pre- and post-treatment science instruction. A new instrument--the Inquiry Matrix--was developed and used to describe and analyze instruction in science classrooms. This paper presents a study being reported for the first time that includes data collected using both the MR-STBI and the Inquiry Matrix. MR-STBI data from three studies reported earlier are included for background reference. The videotaped science instruction from those studies was reexamined using the Inquiry Matrix. Results indicate that the Inquiry Matrix instrument was effective in defining and describing inquiry in terms of levels of inquiry of both modeled science instruction and classroom instruction. Eliminating certain non-academic strategies or behaviors from the MR-STBI results in teaching profiles that are significantly closer to the desired instruction. Contains 22 references. (Author/PVD)

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EVALUATING THE USE OF THE INQUIRY MATRIX

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Evaluating the Use of the Inquiry Matrix.

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Reported during this paper set will be a comparison of the results of using the Modified-Revised Science Teacher's Behavior Inventory (MR-STBI) and the Inquiry Matrix in describing teaching strategies emphasized by four different groups of science teachers at the school and beginning college levels in instruction that was designed to be laboratory-data driven. Because of the complexity of the MR-STBI and because of a need to more functionally define "inquiry" based-instruction, a new instrument, the Inquiry Matrix was developed and used to describe and analyze instruction in science classrooms. The results from the Inquiry Matrix description of instruction were then compared to instructional sequences previously described using the MR-STBI. The results indicate the effectiveness of the Inquiry Matrix instrument in defining and describing inquiry in terms of "levels of inquiry" of both modeled science instruction and classroom instruction compared to this model. The results of the use of both instruments indicated that eliminating certain "non-academic" strategies or behaviors from the MR-STBI results in teaching profiles that are significantly closer to the desired instruction.

Rationale and Overview

Over many years, concern has been expressed by some researchers and policy developers that laboratory based experiences in science instruction have not met their potential in developing higher order thinking behaviors (and other process skills) that have been shown by U.S. Department of Labor Studies to be critical to success in the workforce. According to the National Science Education Standards (1996) "This nation has established as a goal that all students should achieve scientific literacy. ...emphasize a new way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding ..." (1996, p. ix). The research to be reported is directly related to the results of 9 earlier studies that were designed to address the question: how can learning outcomes be improved from science laboratory experience in elementary, middle, high school and beginning college level science instruction? Stated in a more practical way: how can teachers assure that laboratory based science instruction is worth the effort and expense?

Earlier reported studies utilized the Modified Revised - Science Teacher's Behavior Inventory (MR-STBI) to analyze the teaching strategies emphasized in instruction in science classrooms and then determined changes in teaching strategies that occurred as a result of science teachers' professional development through longer-term modeled laboratory driven instruction, group planning for such instruction and mentoring by college level faculty as teacher taught science back in their schools. All four of the studies included in this paper set used the MR-STBI to analyze the instructional strategies emphasized by teachers. MR-STBI data from three of the studies reported earlier are used for purposes of background reference. The White (1997) study, being reported for the first time, includes data collected using both the MR-STBI and the Inquiry Matrix.

As an outgrowth of these earlier studies, it became clear that the MR-STBI, through use, did not address effectively, the extent of inquiry in pre- and post-treatment science instruction. Therefore, the research team rigorously examined the literature on "inquiry" and building on this examination developed the Inquiry Matrix and used it in re-examining the videotaped science instruction recorded in the earlier studies as well as with current research.

Brief Review of Previous Reported Study Findings.

Table 1 summaries the major findings from the earlier studies based on use of the MR-STBI.

The Science Teacher Behavior Inventory (STBI) was developed and used by Vickery (1968) and revised as the R-STBI by Clark (1974). The R-STBI was further modified by Hilosky (1994) and Wang (1997) and labeled MR-STBI. This modified revised form included strategies or behaviors that reflect more recently used teaching strategies such as: the use of technology (computers) interactive video discs, as well as behaviors allied with the constructivist learning theory. The section of the MR-STBI entitled Teacher Centered Pre-Post Laboratory Activity has been utilized in 8 studies conducted through the Center for Science Laboratory Studies. Two of these studies were concerned with learning outcomes at the elementary school level. The researchers carrying out these studies needed to modify the MR-STBI further in order to be able to: (1) include behaviors that were specifically related to this level; for example, teacher interacting with another adult

Table 1. Summary of Four Companion Studies Utilizing the MR-STBI.

Researcher	Level	Brief Description of Studies	Major Findings
M. White (1997)	Elementary	Research was designed to explore the impact of industrial volunteer/school partnerships on science teaching behaviors. Researcher randomly selected three experimental schools and teachers worked directly with an industrial partner; the third school served as a control. A second suburban district was selected as a comparison school and a scientist (no training in science education) participated as an industrial volunteer.	Although the teachers involved thought the support was helpful and should be continued, the modeled instruction carried out in this type of partnership did not influence the types of teaching behaviors used during science instruction. Especially significant is that neither questioning wait-time nor level of questions asked was effected by the partnership experience. The experience did not lead to teachers exhibiting a more constructivist-oriented approach to science instruction.
H. D. Priestley (1996)	Middle and Senior High School Life Science	Research explored the impact of modeled longer-term inservice experiences on reforming pre- and post-laboratory science instruction. Modeling of a reformed inquiry-oriented "laboratory-first" approach to science instruction was presented during a semester long course in science pedagogy. The behavior profiles developed were compared to that of the traditional and the modeled-reformed instruction.	70% approached the modeled instruction 30% did not follow the modeled approach
W. J. Priestley (1997)	Senior High School Physical Science	Research explored the impact of modeled longer-term inservice experiences on reforming pre- and post-laboratory science instruction. Modeling of a reformed inquiry-oriented "laboratory-first" approach to science instruction was presented during a semester long course in science pedagogy. The behavior profiles developed were compared to that of the traditional and the modeled-reformed instruction.	79% approached the modeled instruction 21% did not follow the modeled approach Physical science teachers spent, on the average, twice as much time in post-laboratory presentations as did the life science teachers. Physical science teachers presented lesson sequences closer to the model (than did the life science teaches)
A. Hilosky (1994)	College	Research determined present practice in teaching the laboratory component of chemistry instruction in two types of beginning college chemistry courses	The laboratory presented as an add-on to the lecture rather than the "driving force" for instruction Most of instructor's time was devoted to listening to and responding to procedural questions. Almost no time spent in activities designed to develop or strengthen higher order thinking skills.

(2) to meet specific needs other behaviors were added such as: *talks to laboratory assistant, signs pass in/out of room, answers PA system.* interactive video discs, as well as behaviors allied with the constructivist learning theory.

It became clear that for each new study the MR-STBI had to be modified further, making the instrument too complex. Therefore, the decision was made to design a simpler instrument to address the extent to which instruction is inquiry oriented. This instrument, the *Inquiry Matrix* and its use are being reported on here.

Reported Findings Based Upon the Inquiry Matrix.

The laboratory experience in science education inherently involves a wide range of possibly activities, further delineated by the education level (i.e. elementary, secondary, undergraduate level) and laboratory experiences of the student. While individual teacher and/or student behavior/s are an important description of any lesson sequence, such classifications do not allow for a description of the degrees of opportunity for inquiry in science instruction. Earlier developed schemata (Pella 1961, Schwab 1962, Herron 1971, George, Dietz, Abraham and Nelson 1974, Tamir 1976, Hegarty 1978 and McComas 1990) laid the groundwork for a 5 by 6 matrix Inquiry Matrix. The Inquiry Matrix grid elucidates five segments of the inquiry-oriented laboratory lesson (proposes problem or issue to be explored, addresses or plans procedure to be used, explores and carries out procedure, supplies answers or conclusion, Laboratory Outcomes in Follow-up Dialog to Consider Applications and Implications and/or to Drive Further Instruction), the responsibility (teacher or student) for that segment of instruction and the six corresponding levels of inquiry numbered from 0 to 5. The Inquiry Matrix is presented as an overhead.

The Inquiry Matrix, unlike the MR-STBI, is not dependent on certain behaviors being present, or, conversely, certain behaviors being omitted. Rather, the grid is based on who is responsible for the teaching and learning. The National Science Education Standards (1996) emphasizes the importance of/as "central to education, but they must not be placed in the position of being solely responsible for reform. ...students must accept and share responsibility for their own learning" (p. 27). It is possible through use of the Inquiry Matrix to describe the extent to which teachers and students of science are responsible for teaching and learning. As one moves down the matrix more and more responsibility for students in the teaching/learning process in indicated, and less and less responsibility for teachers.

Findings from studies based upon the use of the Inquiry Matrix which compares the results of its use when compared against the MR-STBI is reported below in Table 2.

Table 2. Inquiry Matrix Findings (Compared to Use of the MR-STBI).

Researcher	School Level	Comparisons of Evaluations of Science Instruction Utilizing the MR-STBI and the Inquiry Matrix:
M. White (1997)	Elementary	Findings were in agreement.
H. Priestley (1996)	Middle and Senior High School Life Science	Increase in the percentage of teachers that approached the modeled instruction.
W. J. Priestley (1997)	Middle and Senior High School Physical Science	Increase in the percentage of teachers that approached the modeled instruction
A. Hilosky (1994)	College	Findings were in agreement.

Comparison of the MR-STBI and Inquiry Matrix

The MR-STBI is a sturdy instrument which effectively describes every behavior in a classroom, allowing for a comprehensive picture of the total instructional unit. However, often this behavior by behavior description is too detailed and actually too restrictive in its scope. Early on in H. Priestley's (1996) research it was noted that the Life Science instructors often did not collect the same type(s) of data in the laboratory that necessitated various other approaches than seen in the Physical science classes. When these Life science instructional sequences were compared to a modeled instruction it produced a division which made it appear that they were not following the modeled approach, while, in actuality, the differences were merely reflecting the distinction in subject matter. Additionally, not only does the Inquiry Matrix allow for these differences in (appropriate) discipline-embedded behaviors it also encourages them.

The MR-STBI is still an important tool in describing every behavior exhibited by an instructor during a lesson sequence. However, if an instructor is to attempt more of an inquiry-oriented instruction then there must be a provision to support their effort. The Inquiry Matrix allows for an over-all and broad examination of the laboratory experience based on whom is responsible for which element of instruction. Additionally, the Matrix also allows an instructor to plan for a specific level of inquiry instruction without restricting the behaviors necessary to bring about that instructional level. Table 3 compares the various aspects of the Inquiry Matrix and the MR-STBI.

In order to support instructors in presenting laboratory experiences that proceed from Level 0 towards Level 5 on the Inquiry Matrix, teachers of science will require longer-term teacher enhancement support that is modeled and practiced under mentoring. The inservice experience must also include the involvement of teachers in reflecting upon how they teach. The Inquiry Matrix can provide an important function in this regard.

Table 3. Usage Comparison of the MR-STBI and the Inquiry Matrix.

Consideration	MR-STBI	Inquiry Matrix
Reliability	More rigorous approach to inter-rater reliability	Less rigorous approach to inter-rater reliability
Time	Labor intensive	Quick
Equipment	• Video camera (and tripod) • VCR • Monitor • Tapes • Instrument which includes election of classroom activity scale from several different categories of classroom activities	• Paper and pencil • Copy of the Matrix
Expertise in pedagogy	Expert	Novice
Cost	Expensive	Inexpensive

Uses	• Assess many aspects of student learning
	• Instructional behaviors individually listed
	• Use of equipment and laboratory architecture such as
	  ▪ Patterns of instructional behaviors
	  ▪ Use of technology and modern analytical equipment
	  ▪ Safety
	  ▪ Higher order thinking (questions/answers)
	  ▪ Social interaction
	  ▪ Room/Laboratory design such as bench/hood locations, lighting, flooring
	  ▪ Laboratory based outcomes
	• Provides level of inquiry only when used with the Inquiry Matrix
		Level of Inquiry only. However, It can be utilized to:
		♦ Plan a lesson sequence
		♦ Evaluate a completed lesson sequence

Consideration	MR-STBI	Inquiry Matrix
Advantages	• Thorough record of all behaviors and conditions during science instruction • Can be used to redesign instructional experiences to a more inquiry oriented instruction • Allows the instructor to evaluate what is occurring to support or impede instruction • Easy to revise in specific instructional settings (add, subtract or modify categories) • Easy to revise and update as teaching methodologies and technology changes.	• Inexpensive • Quick • Clearly describes the level of inquiry • Instructor is able to evaluate their own instructional level • Instructor is able to plan instruction to improve the level of inquiry or attempt a specific level of inquiry
Disadvantages	• Expensive • Labor intensive and cumbersome • Expert needed • Difficulty in providing "lay" feedback • Often too descriptive and limiting • Not necessarily reflective of appropriate inquiry-oriented instruction • Behaviors exhibited are often age-level, situational or experiential dependent • May be too narrow in defining a "model" • Too many revisions and modifications in use • Need to constantly revise and update as teaching methodologies and technology changes	• Limited • Behaviors exhibited may not be supportive to the inquiry process, thus providing a false level of actual inquiry instruction • Requires the MR-STBI also be used to fully describe the type of behaviors

Literature Base for the Reported Studies:

The National Science Education Standards (1996) states that "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (p. 31).

Tobin (1990) indicated that an outcome of inquiry-based experiences is that students and teachers work collaboratively and have "opportunities to experience what they are to learn in a direct way as well as the time to think and make sense of what they are learning. Science laboratory experiences are a mechanism whereby students learn with understanding and at the same time engage in the process of constructing knowledge by doing science" (p. 405). According to Sutman (1995), "allowing time to engage in science means initially less content coverage. The end result, however, is uncovering more knowledge and covering less or fewer facts".

Schwab (1962) indicated that the degree of inquiry oriented laboratory experiences is illustrated in the extent of openness associated with (science) experiences. This was elaborated by Herron (1971), with the following matrix:

Table 4. Extent of Openness in Instruction (adapted from McComas, 1990)*.

Level of Discovery	Problems	Ways and Means	Answer
Level 0	Given	Given	Given
Level 1	Given	Given	Open
Level 2	Given	Open	Open
Level 3	Given	Open	Open

*also Tamir, 1971

McComas (1990) viewed the classification of laboratory experiences as providing "some information regarding the relative roles of the teacher or laboratory manual and the student" (p. 3).

Hofstein and Lunetta (1982) questioned the case for laboratory instruction and "suggested further research might be needed to assess its value" (p. 201). They also were critical of past practices in laboratory based instruction and criticized the research related to these practices. Hofstein and Lunetta also cite that earlier studies failed to examine teacher behaviors and how teachers translate the curriculum into teaching practices. They called for research based on objective information about the teachers and teacher-student interactions within laboratory-based instructional settings. Even with Hofstein and Lunetta's challenge too few studies have shown a clear relationship between laboratory experience and its effectiveness on increasing science knowledge (Woolnough and Allsop, 1985; Millar and Driver, 1987; Hodson, 1990).

Newmann and Wehlage, while not science educators, affirmed two persistent maladies that make conventional schooling "inauthentic". These are "Often the work students do does not allow them to use their minds well and the work has no intrinsic meaning or value to students beyond achieving success in the school"(p. 3, 1993).

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